Properties of Linear Contrails Detected in 2012 Northern Hemisphere MODIS Imagery

David P. Duda, Thad Chee, Konstantin Khlopenkov, Sarah Bedka, Doug Spangenburg SSAI, Hampton, VA, US

Patrick Minnis NASA LaRC, Hampton, VA, US

OBJECTIVE & APPROACH

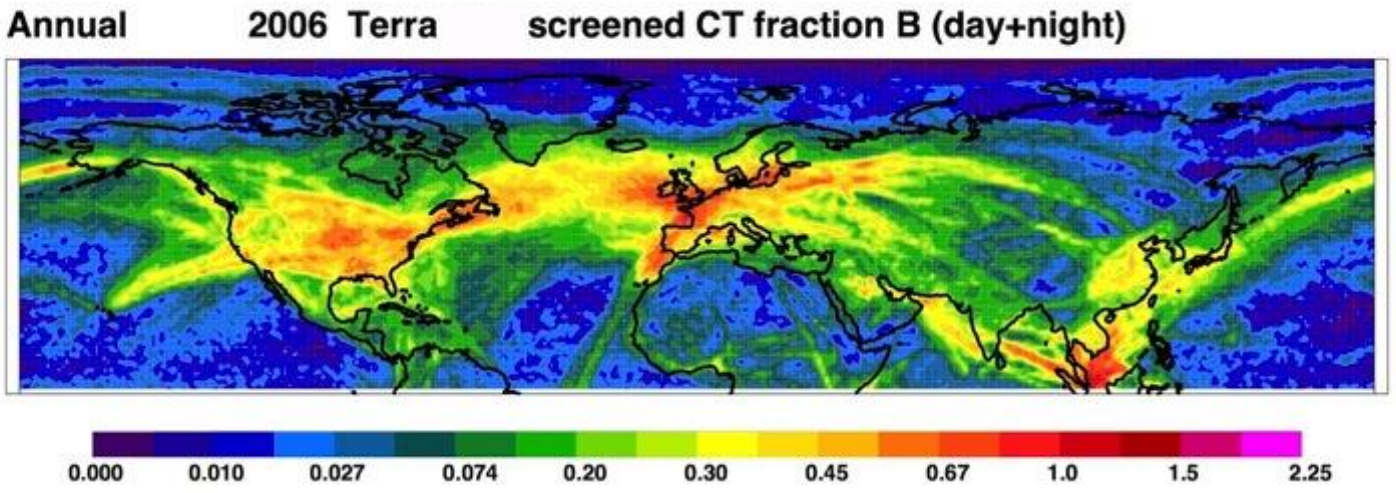
- Develop Northern Hemisphere linear contrail coverage climatology from Terra and Aqua MODIS thermal IR data
  - NH accounts for ~90 percent of contrails
  - Provide the basis for a consistent empirical estimate of contrail radiative forcing & properties for model improvement & validation

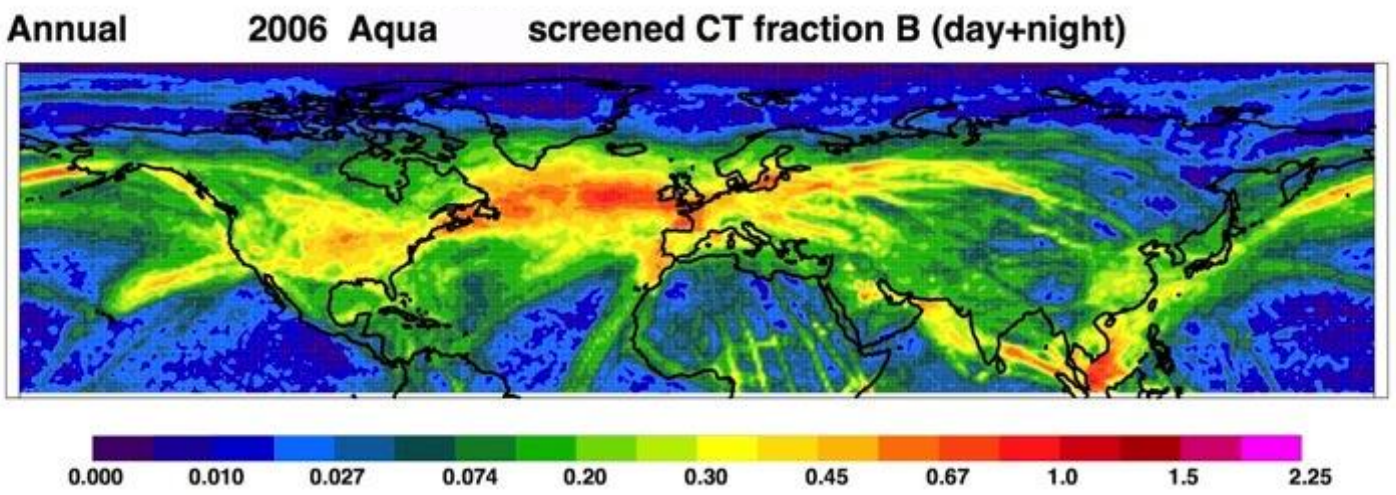
- Estimate coverage of cirrus that is closely associated with detected linear contrails (contrail cirrus?)

Cloud Detection Algorithm

- Modified Mannstein et al. (1999) algorithm with additional thermal IR channels from MODIS
  - Original algorithm developed for AVHRR, extra channels reduce false detection rate of more sensitive MODIS imagery
- Re-projected to standard map to account for distortion at high viewing angles. Fourier frequency processing to remove scan line striping noise while retaining contrail features.
- Global aircraft emissions waypoint data advected forward in time up to 4 h with GEOS-4 (2006 data)/MERRA (2012 data) reanalysis wind profiles to compare detected contrails to flight tracks.

2006 MODIS data



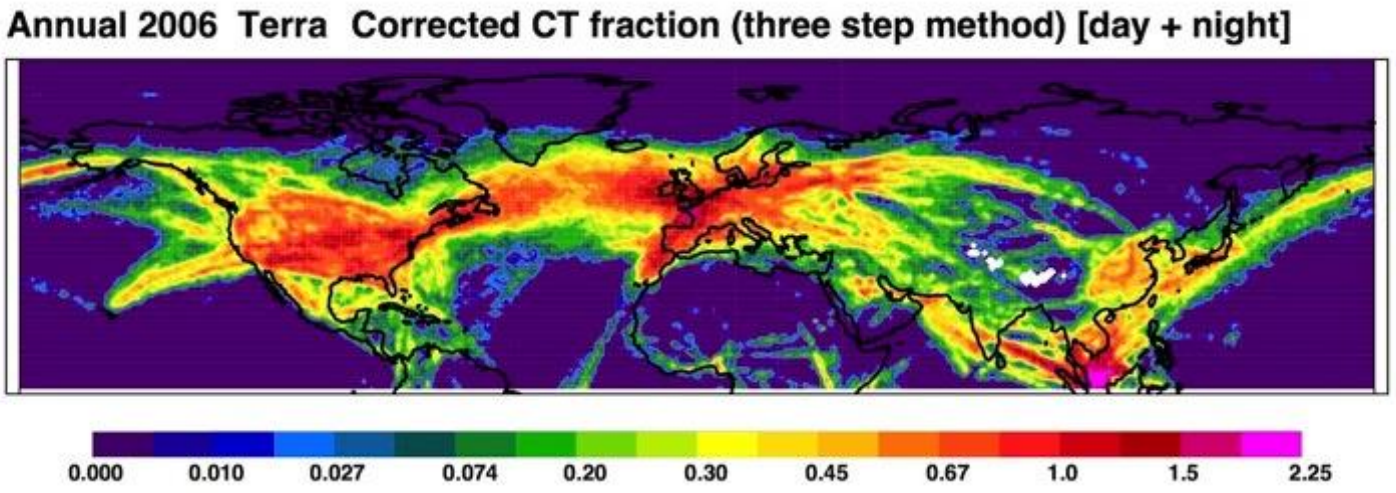


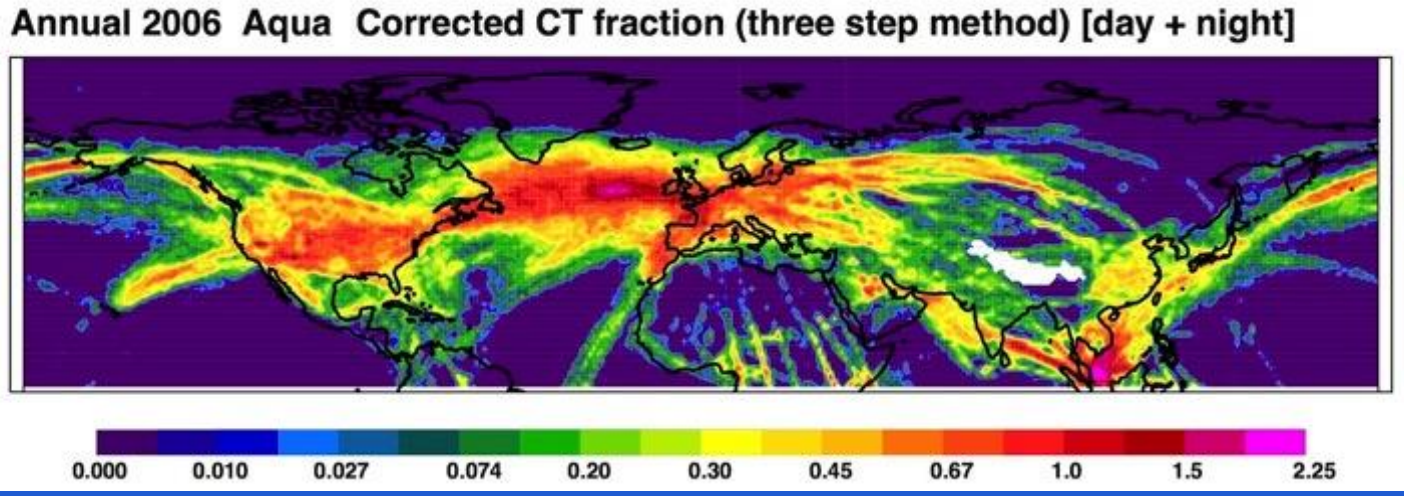
Subjective Visual Analysis

- Evaluate accuracy of CDA by comparing coverage estimates to visual analysis of contrail coverage by human observers of satellite imagery.

- Determine properties of FAR, DEF and STD_{12} to adjust coverage estimates
  - FAR: False Alarm Rate
  - DEF: Detection Efficiency
  - STD_{12}: Standard Deviation of 12-micron BT (proxy for heterogeneity of background thermal IR field)

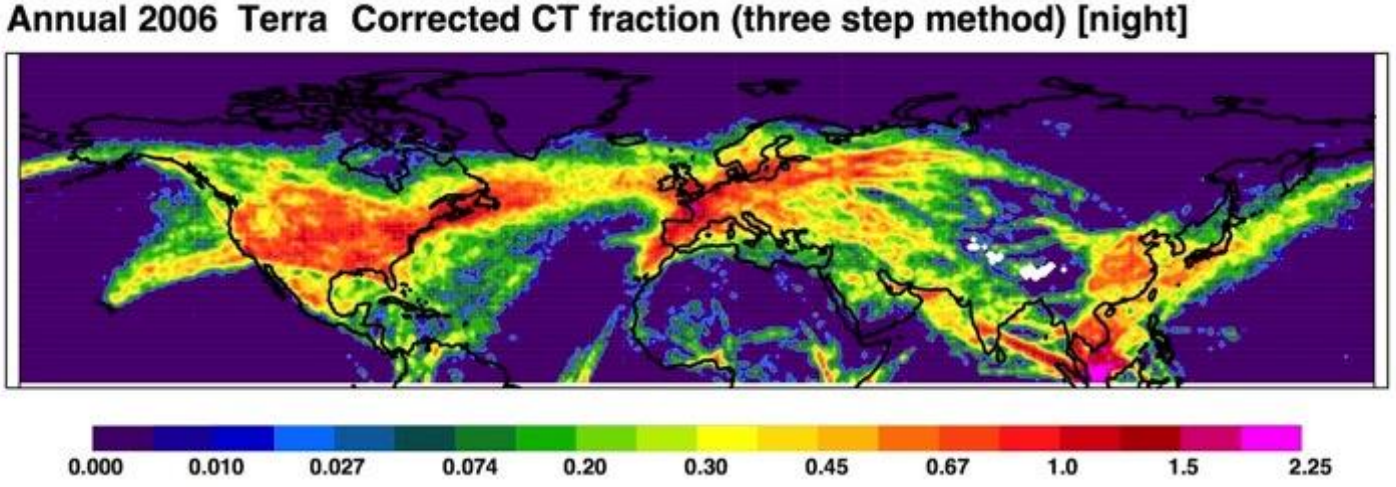
Corrected 2006 MODIS data

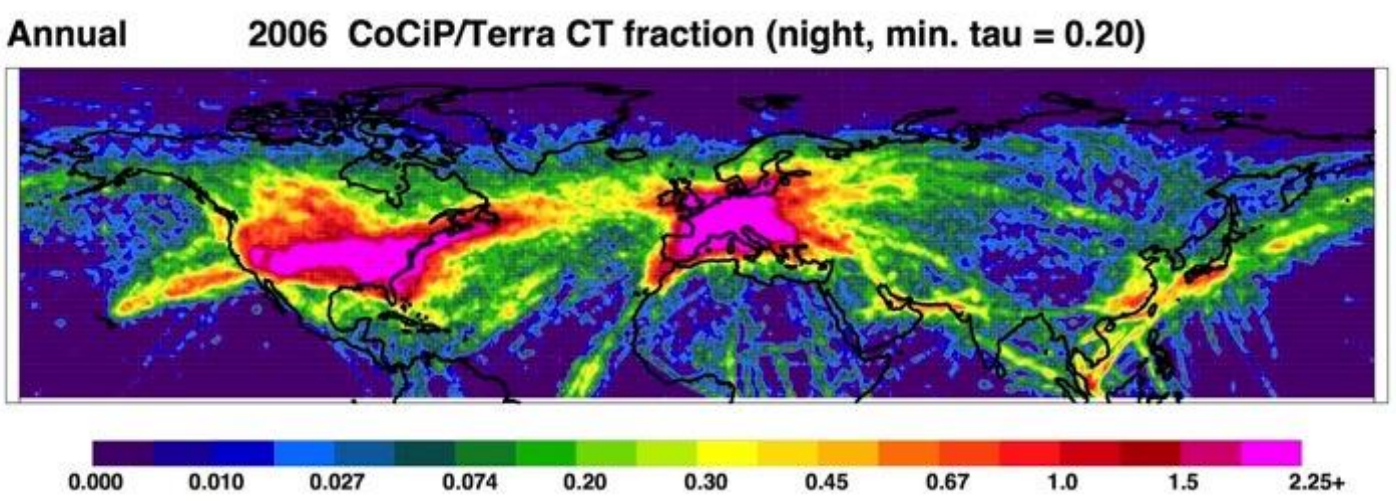




Terra

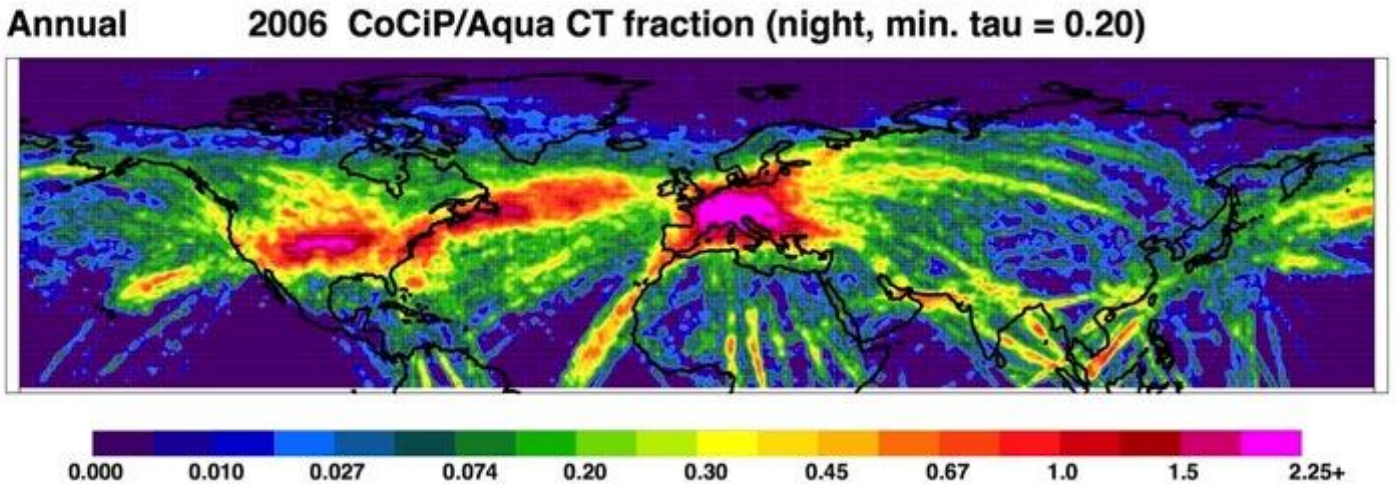
CoCiP coverage filtered by MODIS overpasses

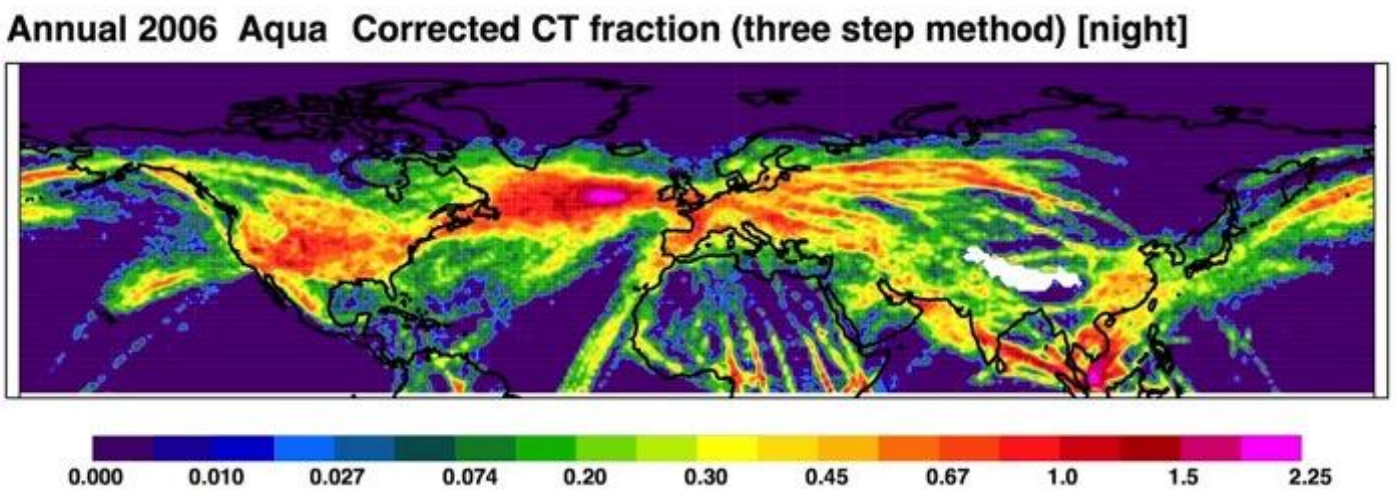




Aqua

CoCiP coverage filtered by MODIS overpasses



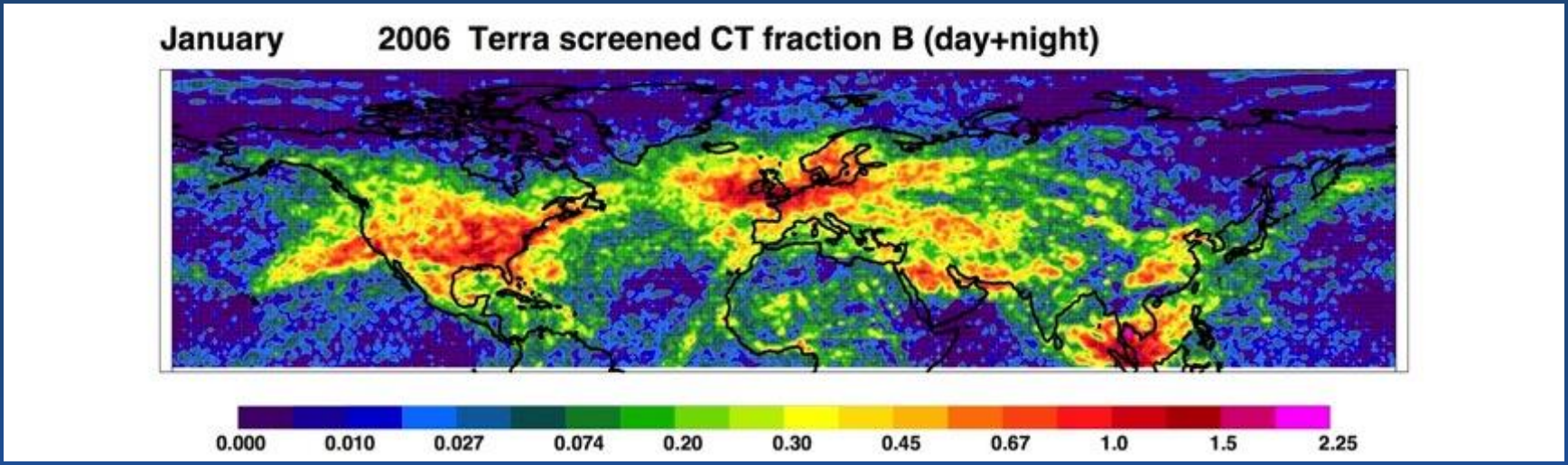


Contrail Detection Algorithm: 2012 data

- Mask B: (same as used in 2006 data)
- Mask D & Mask E: more conservative than Mask B, used as base for contrail widening procedure

January 2012 Terra (day + night)

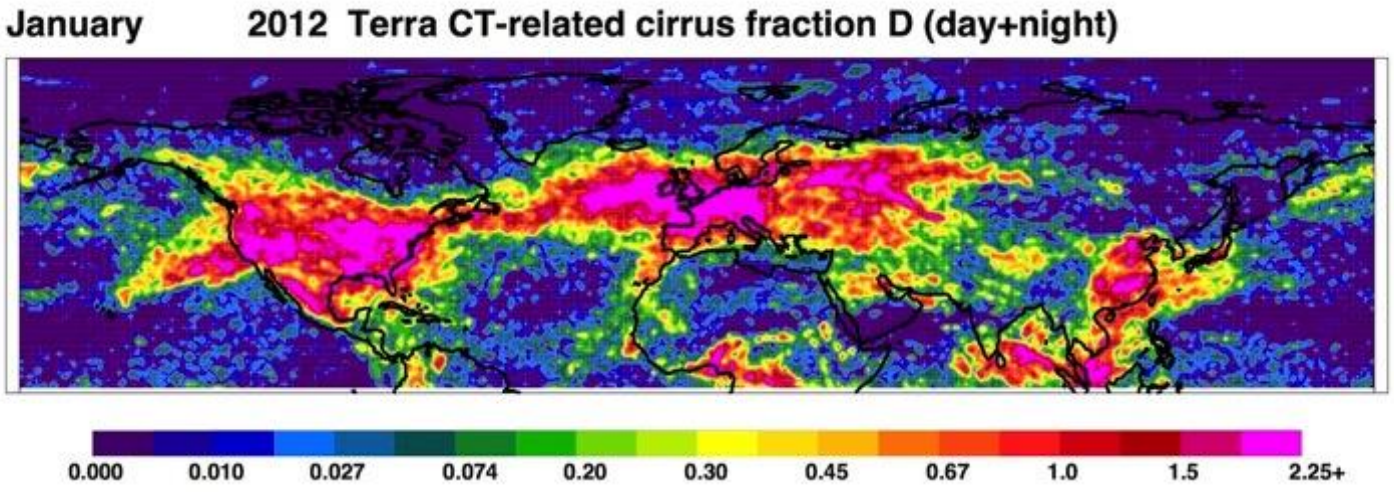
January 2006 Terra (day + night)

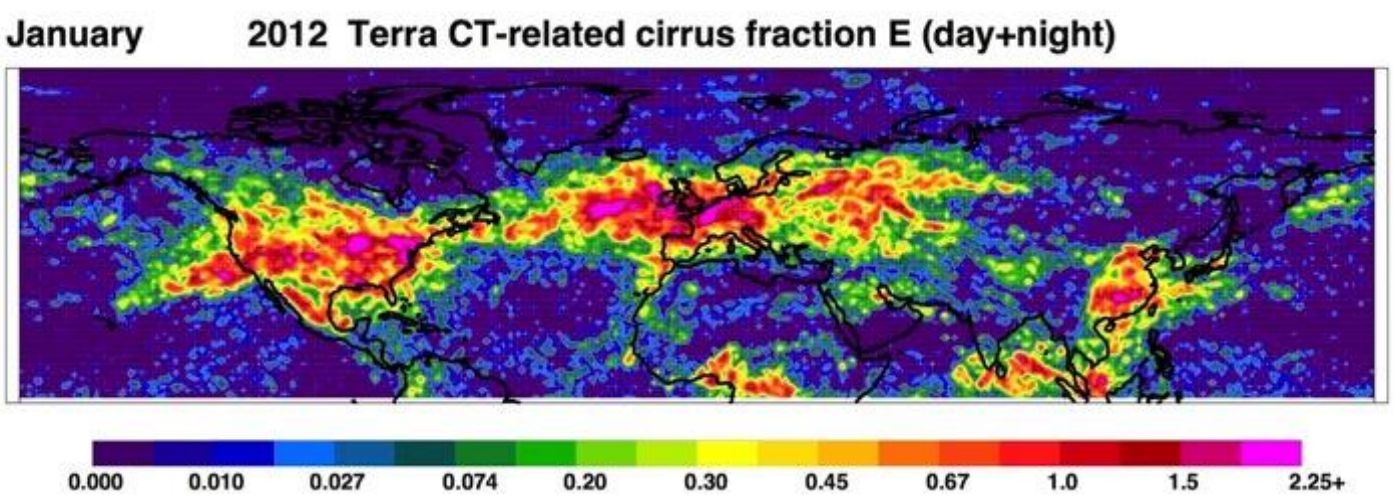


Detection of contrail cirrus

- Compare pixels near detected contrail pixels and add those with similar radiative properties (i.e., similar brightness temperatures)
- Seven threshold tests developed from thermal IR data
  - (11 – 12) micron
  - -13.3 micron
  - -6.8 micron
  - (11 -12) - 13.3 micron
  - (8.6 – 13.3) micron
  - -12 micron
  - 11 – 13.3 micron

Contrail-related cirrus coverage

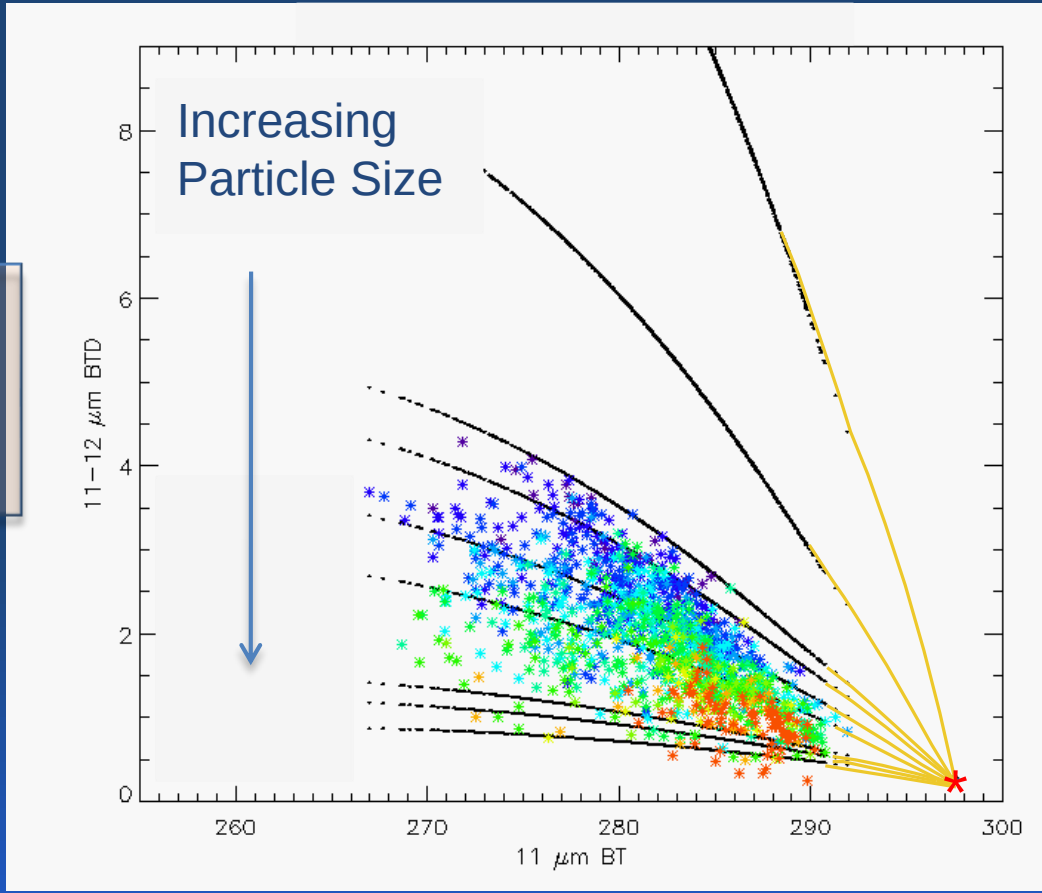




- *Technique minimizes difference between the observed and calculated brightness temperature differences (BTD) for 2 IR bands (11 and 12 μm).*

Retrieving Optical Depth & Particle Size

- Based on method of Inoue (1985)
- Uses 9 hexagonal ice column models (Minnis et al. 1998)
- Accurate contrail temperature and background BTDs key to accurate retrievals
- Retrieve τ and De simultaneously
  - *Contrail temperature input*
    - Assume or use waypoint data
    - Results used in CRF computations



Increasing optical depth

Contrail Radiative Forcing

- Fu-Liou (1993) RTM applied to MODIS pixels
- Upwelling SW and LW fluxes and CRF computed at top-of-atmosphere (TOA)
- Clear, ice cloud or water cloud below contrail are considered; Snow/ice and CERES albedo maps
- CRF calculations done at 1-km MODIS pixel level
- Mean CRF calculated for 1x1° NH grid
- Data filtered with simple first-order flight track screen (air traffic density only)

Future work

- Finish 2012 processing
  - Contrail masks (subjective analysis of linear contrail coverage)
  - Contrail properties (optical depth, particle size)
  - Contrail radiative forcing
- Continue development of contrail cirrus estimates
  - Compare with contrail cirrus identified with geostationary satellite data